the socket 132 seats into the cap 142. The screw 120 is loosely held within the socket 132, which is, in turn, loosely retained within the cap 142.

Referring now to FIG. 7, the rod receiving body member 200 of the present invention is shown in a side view, wherein critical features of the interior of the element are shown in phantom. The body member 200, which comprises a generally cylindrical tubular body having an axial bore 201 extending therethrough, may be conceptually separated into a chamber portion 202 at the bottom of the axial bore 201, and an upper rod receiving channel portion 204, each of which shall be described more fully hereinbelow.

The upper rod receiving channel portion 204 of the body 200 includes a channel 206 formed therein, having rounded bottom surfaces 207. The channel 206, in turn, divides the walls of the cylindrical body of the upper portion 204 into a pair of upwardly extending members 214*a*, 214*b*. As shown in the embodiment illustrated in FIG. 7, the vertical distance from the top 208 of the channel to the curvate bottom 207 thereof, is larger than the diameter of the rod which is to be provided therein. This distance is necessarily larger than the diameter of the rod (see FIGS. 9 and 10) so that the rod may be fully nested in the channel 206. In addition, the depth of the bottom curvate surface 207 of the channel is such that the cap portion 142 of the two-piece interlocking coupling element initially seats above the curvate bottom 207 of the body 200.

The upwardly extending members 214*a*, 214*b* further have, disposed thereon, a threading 216 (which may be provided on the inner and/or outer circumferential surfaces, but which is shown in FIGS. 7, 9 and 10 as being on the inner circumferential surface). This threading 216 is ideally suited for receiving a top locking nut (see FIG. 8).

Referring now to the lower portion of the body, the chamber portion 202 can further be subdivided into a lower chamber portion 203 which includes an inwardly tapered surface, and an upper chamber portion 205 which has a constant diameter. The inwardly tapered portion 203 defines a nesting volume into which the socket portion 132 may nest. Prior to its being fully driven into this nesting volume, the socket portion 132 and the screw 120 disposed therein may be angulated relative to one another, and the screw 120 may be angulated relative to the body 200. Once driven fully into the tapered lower chamber portion 203, however, the taper of the axial bore 201 provides the necessary inwardly directed radial force to cause the socket portion 132 to crush lock to the head 122 of the screw 120.

The force which causes the socket portion 132 to be driven downwardly into the tapered lower chamber portion 203 is provided by the cap portion 142. More specifically, as stated above, when the initially assembled screw 120 and coupling element combination 132 and 142 (see FIG. 6) is advanced into the bottom of the axial bore 201 of the body 200, and the socket portion 132 nests in the lower chamber portion 203, the top of the cap portion 142 is positioned to receive the rod (see FIGS. 9 and 10) directly thereon. The locking of the rod in the channel 206 of the body 200 causes the cap portion 142 to be forced downwardly onto the socket portion 132, which in turn drives the socket portion 132 into the tapered lower chamber portion 203 and causes it of compression lock to the head 122 of the screw 120.

Referring now to FIG. 8, a top locking nut 185 is shown in side cross-section view. The nut 185 comprises post portion 186 and a flange portion 187, each of which is rotationally free, relative to the other. The post portion 186 includes a threading 188 thereon, for engaging and advancing along a threading 216 on the inner surface of the upwardly extending members 214*a*, 214*b* of the upper portion 204 of the body 200. The bottom surface 189 of the flange portion 187 (which does not rotate relative to the body as the post portion 186 is rotationally advanced) is intended to seat against the top surface of the rod 250.

Referring now to FIG. 9, in which the fully assembled and body member 200, screw 120, coupling element portions 132 and 142, rod 250 and locking nut 185 are shown in side cross-section views, the implantation of this embodiment is described. First, the screw 120 and the two portions 132 and 142 of the coupling element are assembled into their initial association (see FIG. 6). The combination of the screw 120 and the two coupling element portions 132 and 142 are then advanced down the axial bore 201 of the body 200 until the socket portion 132 nests in the lower chamber 203 and the top of the cap portion 142 seats above the bottom 207 of the channel 206. (This insertion of the subassembly of the screw 120 and coupling element portions 132 and 142 into the axial bore 201 of the body 200 may require the threaded advance of the cap portion 142 along the interior threads 216 of the body.)

The shaft of the screw 120 is then inserted and driven downward into the vertebral bone at the desired angle. Once properly positioned, the body 200 is rotated into the ideal rod receiving position. The rod 250 is then inserted into the channel 206 and the top locling nut 185 is threaded onto the threading 216 and compresses the rod 250 to securely lock it in the channel 206. This downward force of the nut 185 and the rod 250 onto the cap portion 142 causes the cap portion to translate downward thus causing the socket portion 132 to translate downward in the tapered chamber 203 and contract to crush against the head 122 of the screw 120. The assembly is thereby fully locked in position.

Referring to FIG. 10, a variation of the above device is shown in a similar cross-section view. In this embodiment, the inner surface 146' of the cap portion 142 is tapered inwardly in the vertical direction so that the downward translation of the cap portion 142 causes the annular lip 140 of the socket portion 132 to be compressed inwardly. This causes the slots 141 of the upper section 139 of the socket portion 132 to narrow. This may be utilized to further clamp the interior volume 134 against the head 122 of the screw 120.

While there has been described and illustrated embodiments of a polyaxial screw and coupling element assembly for use with posterior spinal rod implantation apparatus, it will be apparent to those skilled in the art that variations and modifications are possible without deviating from the broad spirit and principle of the present invention. The present invention shall, therefore, be limited solely by the scope of the claims appended hereto.

We claim:

1. A polyaxial screw and coupling element assembly for use with orthopedic rod implantation apparatus, comprising:

a screw having a semi-spherical head;

a cylindrical body including an axial bore defining a bottom chamber portion at a bottom end thereof and a rod receiving channel at a top end thereof, said bottom chamber portion further defining a tapered lower portion and a constant diameter upper chamber portion, and said top end having a threading thereon;

a two-piece interlocking coupling element including

a socket portion having a semi-spherical interior volume for receiving therein the head of said screw, upper and lower sections, and vertical slots formed

in said upper and lower sections, at least one of said slots rendering said interior volume expandable and contractable, said lower section having a tapered exterior surface for nesting in said tapered lower chamber portion of said cylindrical body such that forceable advancement of socket portion along the tapered lower chamber portion of the axial bore causes the at least one of said slots to narrow such that the semi-spherical interior volume contract, and

a cap portion having an opening in a bottom thereof and an interior chamber extending upwardly therefrom for joining with, and slideably retaining therein, the upper section of said socket portion, said cap portion initially seating with a portion thereof extending into a bottom portion of said rod receiving channel; and

a top locking nut, mateable with said threading, for locking a rod in said channel and for applying therethrough a downward force onto said cap portion,

wherein said semi-spherical head portion is rotationally freely mounted within the semi-spherical interior volume of the socket portion prior to said socket portion being forceably advanced into the tapered lower chamber portion of the axial bore, and

whereby downward compression of a rod in said channel portion of said body member, by said top locking nut, onto the cap portion causes the forceable advancement of the socket portion into the tapered lower chamber portion of the axial bore, and locks the screw, coupling element and body relative to one another.

2. The polyaxial screw as set forth in claim 1, wherein said semi-spherical head of said screw further includes a recess formed therein for receiving therein a screwdriving tool such that said screw may be threadably advanced into a vertebral bone.

3. The polyaxial screw as set forth in claim 1, wherein said threading on said top end is on the interior surface of said channel.

4. The polyaxial screw as set forth in claim 3, wherein said cap portion further includes a threading and wherein said cap portion needs to be threadably advanced along the threading to be seated in the bore into its initial position.

5. The assembly as set forth in claim 1,

wherein said socket portion further comprises a substantially constant diameter upper section having an outwardly annular extending lip at an extreme end thereof,

wherein said opening in the bottom of the cap portion comprises an inwardly directed annular lip, and

wherein at least one of said vertical slots in the upper section of said socket portion renders the upper section thereof to be expandable and contractable such that the upper section of the socket portion may be forceably inserted into the opening in the bottom of the cap portion so that it may be retained in the interior chamber therein by mutual interference engagement of the inwardly directed annular lip of the cap portion and the outwardly extending annular lip of the socket portion.

6. The assembly as set forth in claim 5, wherein the interior chamber of the cap portion comprises a tapered surface such that advancement thereof into the hole causes an inwardly directed force against the upper section of the socket portion, therein causing the at least one of said vertical slots in the upper section to narrow and causes the upper section to contract and further lock the head of the screw within the interior semi-spherical volume of the socket portion.

7. An orthopaedic implant apparatus having a rod and a plurality of screw and coupling element assemblies, comprising:

at least one screw having a semi-spherical head;

at least one cylindrical body including an axial bore defining a bottom chamber portion at a bottom end thereof and a rod receiving channel at a top end thereof, said bottom chamber portion further defining a tapered lower portion and a constant diameter upper chamber portion, and said top end having a threading thereon;

at least one corresponding two-piece interlocking coupling element including

a socket portion having a semi-spherical interior volume for receiving therein the head of said corresponding screw, upper and lower sections, and vertical slots formed in said upper and lower sections, at least one of said slots rendering said interior volume expandable and contractable, said lower section having a tapered exterior surface for nesting in said corresponding tapered lower chamber portion of said cylindrical body such that forceable advancement of socket portion along the tapered lower chamber portion of the axial bore causes the at least one of said slots to narrow such that the semi-spherical interior volume contract, and

a cap portion having an opening in a bottom thereof and an interior chamber extending upwardly therefrom for joining with, and slideably retaining therein, the upper section of said socket portion, said cap portion initially seating with a portion thereof extending into a bottom portion of said rod receiving channel; and

at least one corresponding top locking nut, mateable with said threading, for locking a rod in said channel and for applying therethrough a downward force onto said cap portion,

wherein said semi-spherical head portion is rotationally freely mounted within the semi-spherical interior volume of the socket portion prior to said socket portion being forceably advanced into the tapered lower chamber portion of the axial bore, and

whereby downward compression of a rod in said channel portion of said body member, by said top locking nut, onto the cap portion causes the forceable advancement of the socket portion into the tapered lower chamber portion of the axial bore, and locks the screw, coupling element and body relative to one another.

8. The apparatus as set forth in claim 7, wherein said threading on said top end is on the interior surface of said channel.

9. The apparatus as set forth in claim 8, wherein said cap portion further includes a threading and wherein said cap portion needs to be threadably advanced along the threading to be seated in the bore into its initial position.

10. The apparatus as set forth in claim 7,

wherein said socket portion further comprises a substantially constant diameter upper section having an outwardly annular extending lip at an extreme end thereof,

wherein said opening in the bottom of the cap portion comprises an inwardly directed annular lip, and

wherein at least one of said vertical slots in the upper section of said socket portion renders the upper section thereof to be expandable and contractable such that the upper section of the socket portion may be forceably inserted into the opening in the bottom of the cap portion so that it may be retained in the interior chamber therein by mutual interference engagement of

the inwardly directed annular lip of the cap portion and the outwardly extending annular lip of the socket portion.

11. The apparatus as set forth in claim 10, wherein the interior chamber of the cap portion comprises atapered surface such that advancement thereof into the hole causes an inwardly directed force against the upper section of the

socket portion, therein causing the at least one of said vertical slots in the upper section to narrow and causes the upper section to contract and further lock the head of the screw within the interior semi-spherical volume of the socket portion.

* * * * *